

# Confirmation of neutral buoyancy in *Aethotaxis mitopteryx* DeWitt (Notothenioidei: Nototheniidae)

Thomas J. Near · B. Jacob Kendrick ·  
H. William Detrich III · Christopher D. Jones

Received: 5 May 2006 / Revised: 14 August 2006 / Accepted: 14 August 2006  
© Springer-Verlag 2006

**Abstract** *Aethotaxis mitopteryx* is a nototheniid species with a circum-Antarctic distribution in the Southern Ocean. We present new locality records, buoyancy measurements, and morphometric data on five *A. mitopteryx* specimens collected from the Bransfield Strait. Our analyses demonstrate that *A. mitopteryx* is neutrally buoyant. This result lends additional support to the hypothesis that neutral buoyancy has a single evolutionary origin in Notothenioidei. Food items in these specimens consisted entirely of krill (*Euphausia* sp.), and all specimens were sexually immature. We present morphometric data from these five specimens and compare to the holotype specimen, which is the only *A. mitopteryx* specimen collected in the Ross Sea.

## Introduction

The ecological diversity of the Antarctic notothenioid radiation is characterized by utilization of water column habitats via the reduction of buoyancy (Eastman

1993, 2005). Two notothenioid species, *Pleuragramma antarcticum* and *Dissostichus mawsoni*, are neutrally buoyant as adults, meaning they have negligible weight in seawater (DeVries and Eastman 1978; Eastman and DeVries 1981a; Near et al. 2003). Buoyancy has never been measured on fresh specimens of *Aethotaxis mitopteryx*; however, the species is thought to exhibit neutral buoyancy based on a reduced ossification of the skeleton and a high lipid content (Eastman and DeVries 1982; Hagen et al. 2000).

Additional evidence that *A. mitopteryx* is neutrally buoyant comes from the estimated phylogenetic relationships of notothenioids. Both morphological and molecular phylogenetic analyses indicate that the two confirmed neutrally buoyant nototheniid species (*Dissostichus mawsoni* and *Pleuragramma antarcticum*) are in a clade along with *A. mitopteryx*, *D. eleginoides*, and *Gvozdarus svetovidovi* (Balushkin 2000; Near et al. 2004), which indicates that neutral buoyancy has a single evolutionary origin in notothenioids (Fig. 1).

In this report we present buoyancy measurements for five specimens of the relatively rare *A. mitopteryx* that were captured at three different sampling stations in the Bransfield Strait near the western coast of the Trinity Peninsula. We also compare meristic and morphometric data from these five specimens to the holotype specimen of *A. mitopteryx* from the Ross Sea (DeWitt 1962).

## Materials and methods

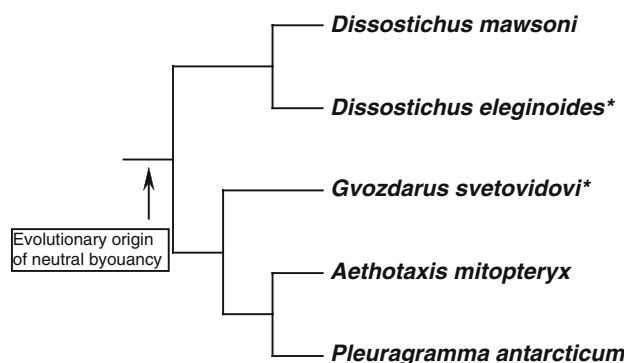
Specimens of *A. mitopteryx* were collected in the Bransfield Strait in February and March 2006. These collections were made during a demersal finfish trawl

---

T. J. Near (✉) · B. J. Kendrick  
Department of Ecology and Evolutionary Biology,  
Yale University, New Haven, CT 06520, USA  
e-mail: thomas.near@yale.edu

H. William Detrich III  
Department of Biology,  
Northeastern University,  
Boston, MA 02115, USA

C. D. Jones  
US Antarctic Marine Living Resources Program (AMLR),  
Southwest Fisheries Science Center,  
8604 La Jolla Shores Drive,  
La Jolla, CA 92037, USA



**Fig. 1** Phylogenetic relationships of neutrally buoyant notothenioid species inferred from both molecular and morphological data. *Gvozdarus svetovidovi* was not included in molecular phylogenetic analyses. Buoyancy measurements are unavailable for species marked with an asterisk

survey aboard the *R/V Yuzhmorgeologiya* conducted by the US Antarctic Marine Living Resources (AMLR) Program to characterize demersal finfish biomass, species composition, and spatial distribution for use towards management of finfish resources by Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Sampling was conducted using a two warp commercial bottom trawl with an average mouth width of 17.0 m and height of 10.0 m; the trawl was deployed with 1 ton vented V-doors. Each trawl sample lasted approximately 25–30 min.

Immediately after emptying the contents of the trawl, *A. mitopteryx* specimens were placed in seawater between 0.9–1.4°C and then anesthetized using MS-222. All specimens were assigned field numbers (YFTC: Yale Fish Tissue Collection). Buoyancy of each specimen was measured using methods outlined in Eastman and DeVries (1982) and Near et al. (2003). Anesthetized specimens were photographed using a small “squeeze tank” that was constructed with 0.5 cm thick window glass and silicone aquarium sealant. The dimensions of the assembled tank were approximately 40.0 × 29.5 × 6.0 cm<sup>3</sup> (height/width/depth). A piece of window glass with polished edges measuring 0.3 cm thick and 39.0 × 31.0 cm<sup>2</sup> served as a press plate. When photographing a specimen, the tank was filled with distilled water and the specimen was placed in the tank and positioned between the press plate and front pane of the squeeze tank. A Nikon Coolpix 4300 was mounted on a tripod and standard indoor florescent lighting was used to illuminate the squeeze tank. Colour fidelity was assured by setting the camera to the auto-white-balance mode. A light blue matte poster board was placed behind the squeeze tank and a black poster board measuring 45.0 × 38.0 cm<sup>2</sup> was used as a

shield for the camera by cutting a hole in the center to fit the lens.

After measuring buoyancy and taking photographs, we dissected each specimen to determine sex, a five-point qualitative sexual maturity score (Everson 1977), and characterization of stomach contents. Tissue biopsies were collected for future genetic analysis. Specimens were fixed in 10% buffered formalin (treating saturated formaldehyde as 100%) for approximately 7 days, washed in fresh water for 2 days, and transferred to 70% ethanol for long-term preservation. All specimens were deposited in the Yale Peabody Museum of Natural History Fish Collection (Moore and Boardman 1991).

Meristic and morphometric data were collected from the left side of specimens following protocols outlined in Hubbs and Lagler (1958), except that the length of the upper lateral line was determined by noting where it terminated relative to the second dorsal fin. Four morphometric characters were examined, and all were expressed as ratios of SL. The meristic and morphometric data from these specimens were compared to counts and measurements reported for the holotype specimen in DeWitt (1962), and to data presented in Kotlyar (1978), Miller (1993), and DeWitt et al. (1990).

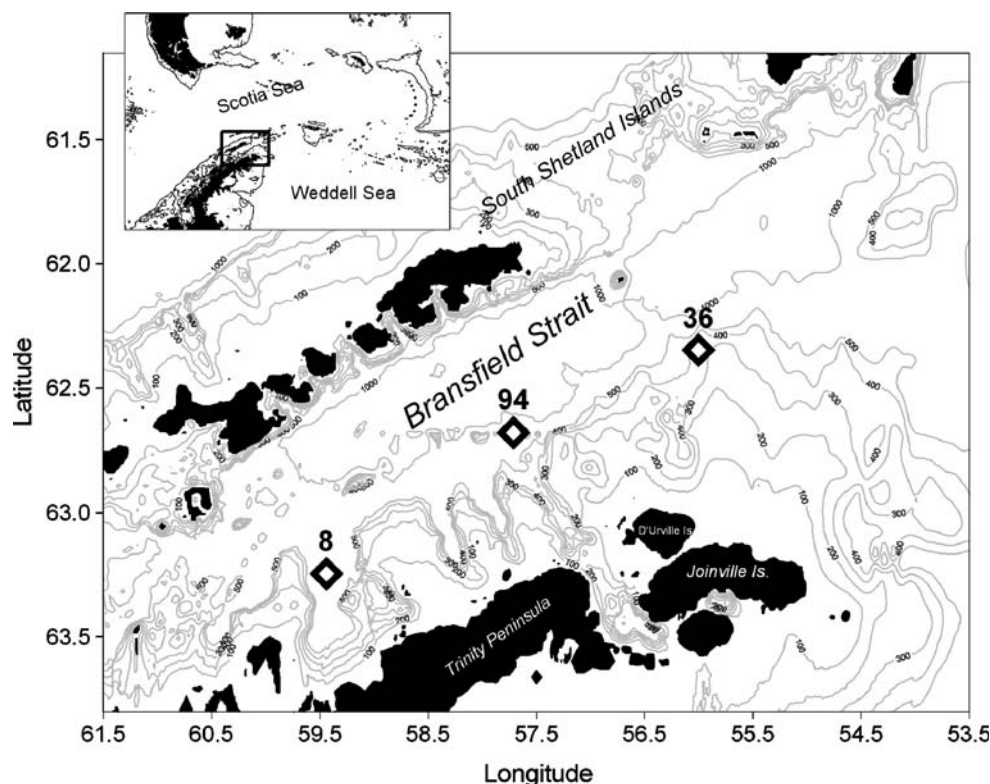
## Results and discussion

Five specimens of *A. mitopteryx* were collected at three trawling stations in the Bransfield Strait (Table 1; Fig. 2). *Aethotaxis mitopteryx* exhibits a circum-Antarctic distribution, with the species being reported from the Ross Sea (DeWitt 1962; Donnelly et al. 2004), the Weddell Sea (Hubold and Ekau 1987; Ekau 1990), Lazarev Sea (Kunzmann and Zimmermann 1992; Trunov 1999), South Sandwich Islands (Permitin 1969), South Shetland Islands (Kotlyar 1978; Takahashi and Iwami 1997), South Orkney Islands (Permitin 1966), Prydz Bay, and Gunnerus Ridge (Gerasimchuk and Piotrovskiy 1980). Our collections add new distributional records for this species along the western side

**Table 1** Data for trawling stations where *Aethotaxis mitopteryx* was collected

Station	Midpoint latitude	Midpoint longitude	Mean depth (m)	Date
8	63°14.67'S	59°26.48'W	755	21 Feb 2006
36	62°20.86'S	56°00.20'W	352	25 Feb 2006
94	62°40.64'S	57°42.63'W	730	15 Mar 2006

**Fig. 2** Collection localities of *Aethotaxis mitopteryx* in the 2006 survey of the Bransfield Strait-Trinity Peninsula area



of the Trinity Peninsula within the Bransfield Strait (Fig. 2).

All specimens had noticeable pigmentation in the dorsal, anal, pelvic, and caudal fins (Fig. 3). The oral cavity of these specimens was nearly black due to heavy pigmentation contributed by melanophores, and there was extensive melanism of the peritoneum, stomach and digestive tract (Eastman and DeVries 1997). Three of the specimens were male, one was female, and the sex of the smallest specimen was indeterminate (Table 2). The body, fin rays, and membranes between fin spines were heavily peppered with melanophores. The coloration of the body was a light iridescent violet-gray (Fig. 3). All specimens contained immature

gonads. Three of the five specimens had food items in their stomachs that were composed entirely of krill (*Euphausia* sp.).

Each of the five Bransfield Strait *A. mitopteryx* specimens weighed 0 g in water (Table 2), which confirms the hypothesis that *A. mitopteryx* is neutrally buoyant (Eastman and DeVries 1982; Eastman 1993). The demonstration of neutral buoyancy (Table 2), the presence of the species in deep water, a diet composed of krill (Takahashi and Iwami 1997), and ecomorphological analyses (Klingenberg and Ekau 1996) all indicate that *A. mitopteryx* is probably a permanent inhabitant of pelagic habitats.

Meristic and morphometric data for the five specimens and the holotype specimen from DeWitt (1962) are presented in Table 3. There was strong similarity in meristic characters between the Bransfield Strait



**Fig. 3** Photograph of an anesthetized *Aethotaxis mitopteryx* specimen YFTC 7984, YPM 15249 collected on 15 March 2006 at a depth of 730 m. The standard length is 16.8 cm

**Table 2** Standard length (SL), weight in air ( $W_{\text{AIR}}$ ), weight in water ( $W_{\text{WATER}}$ ), and buoyancy (%B) for *Aethotaxis mitopteryx* specimens

Specimen	Catalogue number	Station	SL (cm)	$W_{\text{AIR}}$ (g)	$W_{\text{WATER}}$ (g)	%B
YFTC 7768	YPM 15247	8	14.8	31.4	0.0	0
YFTC 7821	YPM 15248	36	15.1	32.4	0.0	0
YFTC 7984	YPM 15249	94	16.8	43.7	0.0	0
YFTC 7985	YPM 15249	94	15.9	43.4	0.0	0
YFTC 7986	YPM 15249	94	18.4	59.2	0.0	0

**Table 3** Morphometric data for Bransfield Strait *Aethotaxis mitopteryx* specimens

Specimen	Station	Sex	SL (cm)	DI	DII	Anal Rays	Pectoral Rays	HL/SL	IOD/SL	BD/SL	ED/SL
YFTC 7768	8	?	14.8	6	34	31	27	0.260	0.061	0.143	0.063
YFTC 7821	36	F	15.1	7	33	31	28	0.230	0.058	0.140	0.054
YFTC 7984	94	M	16.8	7	32	31	29	0.232	0.057	0.137	0.059
YFTC 7985	94	M	15.9	8	32	28	26	0.268	0.060	0.161	0.068
YFTC 7986	94	M	18.4	9	33	30	26	0.245	0.059	0.145	0.060
<b>Holotype</b>		<b>F</b>	<b>35.7</b>	<b>7</b>	<b>34</b>	<b>30</b>	<b>27 or 28</b>	<b>0.294</b>	<b>0.068</b>	<b>0.210</b>	<b>0.063</b>

Characters include standard length (SL), number of spines in first dorsal fin (DI), number of rays in second dorsal fin (DII), ratio of head length (HL) to SL, ratio of interorbital distance (IOD) to SL, ratio of body depth (BD) to SL, and ratio of eye diameter (ED) to SL. Data from the holotype specimen as presented in DeWitt (1962) is given in bold

specimens and the holotype (Table 3). Prior to this study the reported range of first dorsal fin spines was 7–8 (Kotlyar 1978; Gerasimchuk and Piotrovskiy 1980; DeWitt et al. 1990; Miller 1993); however, the range among our five specimens was 6–9 (Table 3). All other meristic character values agreed closely between the Bransfield Strait specimens and the holotype, as well as the reported ranges for these characters (DeWitt et al. 1990; Miller 1993). Three of the four morphometric characters agreed closely with the holotype, but body depth was lower in the Bransfield Strait specimens (Table 3). An upper lateral line was either absent or weakly discernable in three of the five specimens (YFTC 7768, YFTC 7821, and YFTC 7986). In the other two specimens the upper lateral line extended to the 10th (YFTC 7984) and 15th ray of the second dorsal fin (YFTC 7985).

With the confirmation of *A. mitopteryx* as a neutrally buoyant notothenioid species, we provide additional support for the hypothesis that evolution of this character in notothenioids had a single origin (Balushkin 2000; Near et al. 2004). Based on the phylogeny (Fig. 1), reduced ossification of the skeleton, and patterns of habitat and resource use, we predict that both *D. eleginoides* and *Gvozdarus svetovidovi* are neutrally buoyant. Eastman (2005) argues that the close phylogenetic relationships of these species do not require a single evolutionary origin of neutral buoyancy in notothenioids, because these species employ different morphological mechanisms of buoyancy reduction. However, *A. mitopteryx*, *P. antarcticum*, and *D. mawsoni* share in common the phenotypes of reduced skeletal ossification and substantial accumulation of somatic lipids (DeVries and Eastman 1978; Eastman and DeVries 1981b; Eastman 1988, 2005), traits that facilitate neutral buoyancy. Based on the phylogeny, we hypothesize that the diversification of the neutrally buoyant notothenioid clade involved an ancestral condition of subcutaneous lipid deposits, as seen in *D. mawsoni*, and the evolution of a more derived condition of intramuscular lipid deposits seen in *P. antarcticum* (DeVries and Eastman

1978; Eastman and DeVries 1981a, 1982). The fact that there is variability in the morphological mechanisms of neutral buoyancy among the species in this clade is not justification to reject the hypothesis of a single origin of neutral buoyancy, since character diversification can result in the variation observed among species in the traits associated with neutral buoyancy.

**Acknowledgments** We thank Capt. Peter Njardvik, and the officers and crew of the R/V *Yuzhmorgeologiya*. This work was supported in part by NSF grant OPP-0336932 to H.W.D. The US Antarctic Marine Living Resources Program and the Yale Peabody Museum of Natural History provided travel and research collection support.

## References

- Balushkin AV (2000) Morphology, classification, and evolution of notothenioid fishes of the Southern Ocean (Notothenioidei, Perciformes). J Ichthyol 40:S74–S109
- DeVries AL, Eastman JT (1978) Lipid sacs as a buoyancy adaptation in an Antarctic fish. Nature 271:352–353
- DeWitt HH (1962) A new Antarctic nototheniid fish with notes on two recently described nototheniiforms. Copeia 1962:826–833
- DeWitt HH, Heemstra PC, Gon O (1990) Nototheniidae. In: Gon O and PC Heemstra (eds) Fishes of the Southern Ocean. J.L.B. Smith Institute of Ichthyology, Grahamstown, pp 279–331
- Donnelly J, Torres JJ, Sutton TT, Simoniello C (2004) Fishes of the Eastern Ross Sea, Antarctica. Polar Biol 27:637–650
- Eastman JT (1988) Lipid storage systems and the biology of two neutrally buoyant Antarctic notothenioid fishes. Comp Biochem Phys 90B:529–537
- Eastman JT (1993) Antarctic fish biology: evolution in a unique environment. Academic, San Diego
- Eastman JT (2005) The nature of the diversity of Antarctic fishes. Polar Biol 28:93–107
- Eastman JT, DeVries AL (1981a) Buoyancy adaptations in a swim-bladderless Antarctic fish. J Morph 167:91–102
- Eastman JT, DeVries AL (1981b) Hepatic ultrastructural specialization in antarctic fishes. Cell Tissue Res 219:489–496
- Eastman JT, DeVries AL (1982) Buoyancy studies of notothenioid fishes in McMurdo Sound, Antarctica. Copeia 1982:385–393
- Eastman JT, DeVries AL (1997) Morphology of the digestive system of Antarctic nototheniid fishes. Polar Biol 17:1–13

- Ekau W (1990) Demersal fish fauna of the Weddell Sea, Antarctica. *Antarctic Sci* 2:129–137
- Everson I (1977) The living resources of the Southern Ocean. FAO, Rome
- Gerasimchuk VV, Piotrovskiy AS (1980) A find of a rare fish *Aethotaxis mitopteryx* DeWitt, 1962 (Nototheniidae, Osteichthyes) in the Indian Ocean sector of the Antarctic. *J Ichthyol* 20:138–140
- Hagen W, Kattner G, Friedrich C (2000) The lipid compositions of high-Antarctic notothenioid fish species with different life strategies. *Polar Biol* 23:785–791
- Hubbs CL, Lagler KF (1958) Fishes of the great lakes region. The University of Michigan, Ann Arbor
- Hubold G, Ekau W (1987) Midwater fish fauna of the Weddell Sea, Antarctica. In: Kullander SO, Fernholm B (eds) Proceedings of the fifth congress of European ichthyologists. Swedish National Museum, Stockholm, pp 391–396
- Klingenberg CP, Ekau W (1996) A combined morphometric and phylogenetic analysis of an ecomorphological trend: pelagization in Antarctic fishes (Perciformes: Nototheniidae). *Biol J Linn Soc* 59:143–177
- Kotlyar AN (1978) A new discovery of rare fish species, *Aethotaxis mitopteryx* (Fam. Nototheniidae) and *Pseudoichthys australis* (Fam. Centrolophidae) in the South Atlantic. *J Ichthyol* 18:324–326
- Kunzmann A, Zimmermann C (1992) *Aethotaxis mitopteryx*, a high-Antarctic fish with benthopelagic mode of life. *Mar Ecol Prog Ser* 88:33–40
- Miller RG (1993) A history and atlas of the fishes of the Antarctic Ocean. Foresta Institute for Ocean and Mountain Studies, Carson City, Nevada
- Moore J, Boardman R (1991) List of type specimens in the fish collection at the Yale Peabody Museum, with a brief history of ichthyology at Yale University. *Postilla* 26:1–36
- Near TJ, Pesavento JJ, Cheng CHC (2004) Phylogenetic investigations of Antarctic notothenioid fishes (Perciformes: Notothenioidei) using complete gene sequences of the mitochondrial encoded 16S rRNA. *Mol Phylogenet Evol* 32:881–891
- Near TJ, Russo SE, Jones CD, DeVries AL (2003) Ontogenetic shift in buoyancy and habitat in the Antarctic toothfish, *Dissostichus mawsoni* (Perciformes: Nototheniidae). *Polar Biol* 26:124–128
- Permitin YY (1966) New evidence on species composition and distribution of the fishes of the South Scotia Sea (Antarctica). *Vopr Ikhtiol* 6:424–431
- Permitin YY (1969) New data on species composition and distribution of fishes in the Scotia Sea, Antarctica (second communication). *J Ichthyol* 9:167–181
- Takahashi M, Iwami T (1997) The summer diet of demersal fish at the South Shetland Islands. *Antarctic Sci* 9:407–413
- Trunov IA (1999) New data on species of fish from Subantarctic and Antarctic waters of the Atlantic Ocean. *J Ichthyol* 39:488–497